

The Comparative Effects of Fossil Fuel Soot, Biofuel Soot and Gases, and Methane on Regional and Global Climate, Arctic Ice, and Human Health

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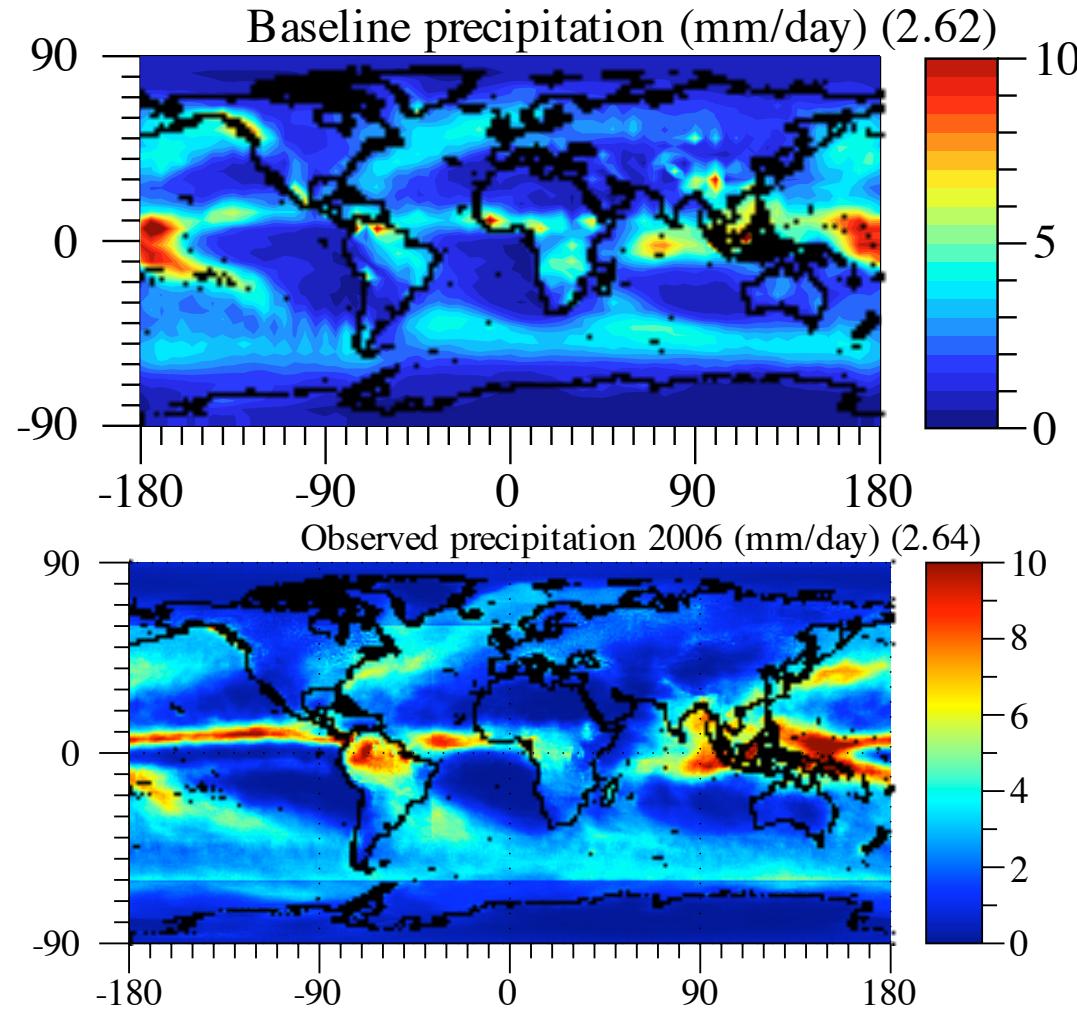
Sacramento, California

Fossil- and Bio-fuel Emissions (Tg/yr)

	Fossil-Fuel	Biofuel
BC	3.2	1.6
POC	2.4	6.5
S(VI)	0.03	0.3
Na ⁺		0.023
K ⁺ as Na ⁺		0.14
Ca ²⁺ as Na ⁺		0.18
Mg ²⁺ as Na ⁺		0.08
NH ₄ ⁺		0.018
NO ₃ ⁻		0.16
Cl ⁻		0.30
H ₂ O-hydrated	calculated	calculated
H ⁺	calculated	calculated
		+ 43 gases

BC/POC from Bond et al. (2004); other emis factors Andreae, Ferek

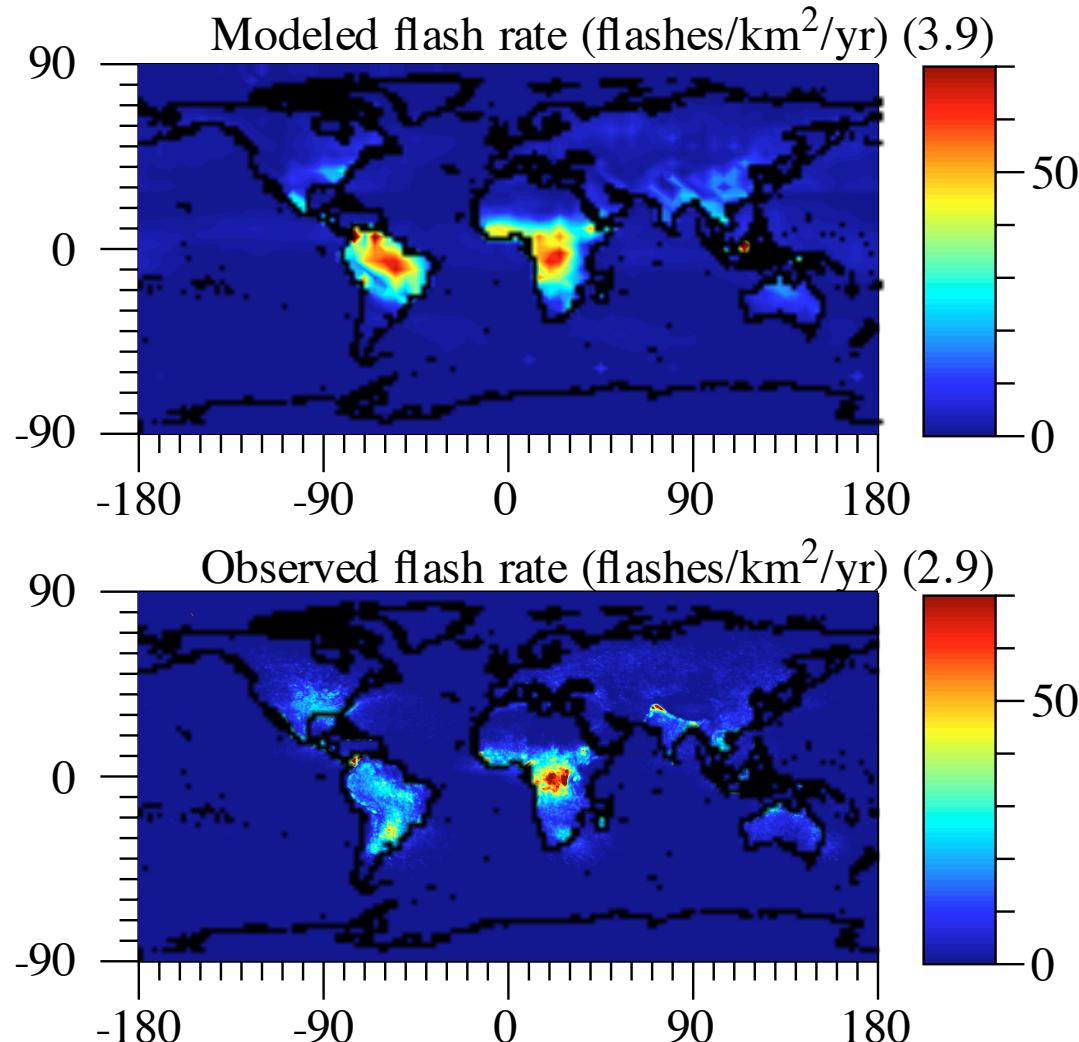
Modeled vs. Measured Annual Precip.



Data from
Huffman et al.
(2007)

Despite factor of 20 lower resolution than data, model predicts locations of main features of observed precipitation and, with no flux adjustment, correctly does not produce a double ITCZ as nearly all models at coarse resolution do.

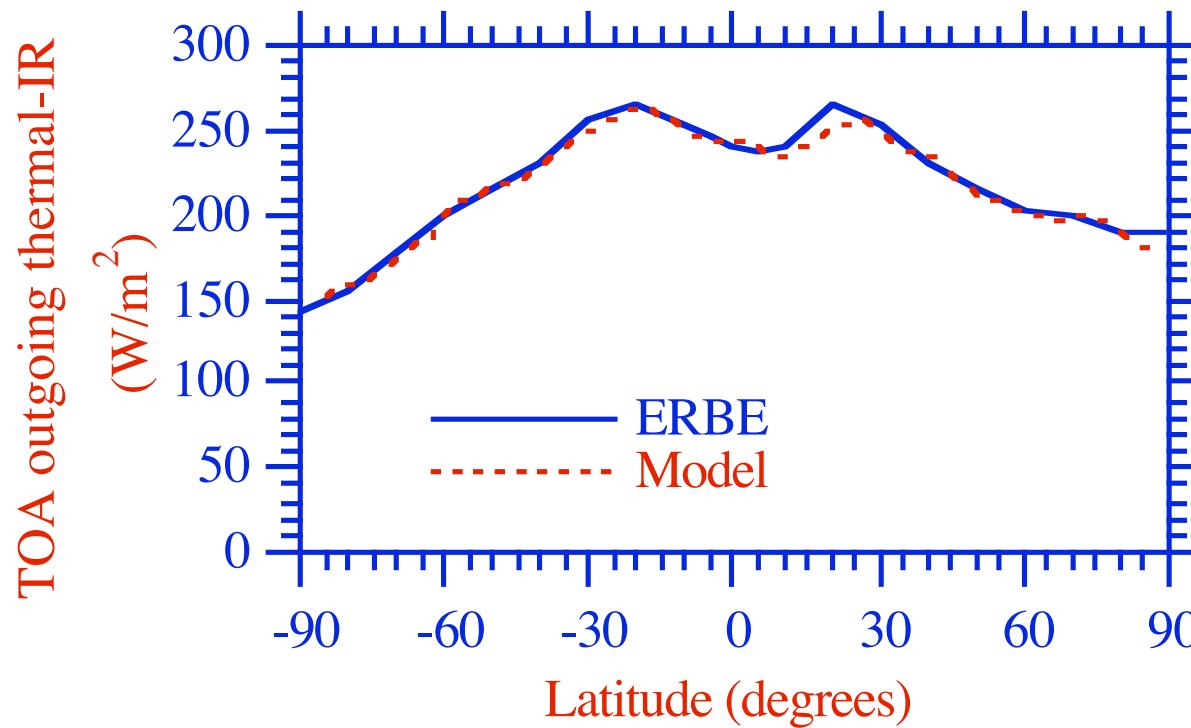
Modeled vs. Measured Annual Lightning Flash Rate



Data from
NASA LIS/OTD
Science Team

Model calculates lightning by accounting for size-resolved bounceoffs and charge separation in clouds. It predicts nearly the magnitude and the location of the peak observed lightning (Congo) and most locations of lightning.

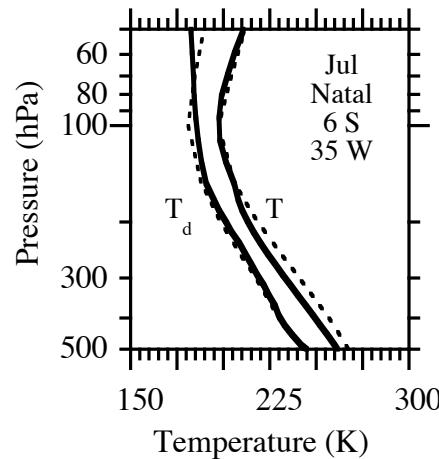
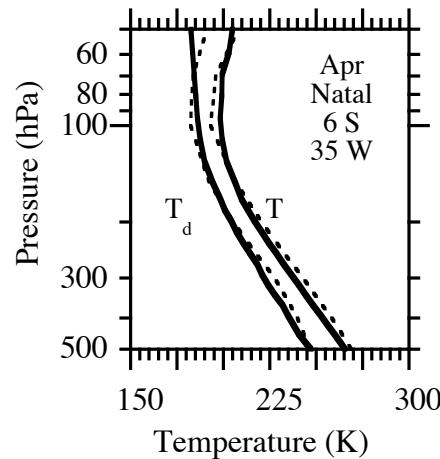
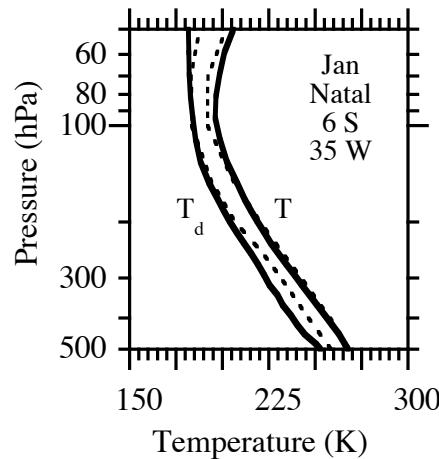
Modeled vs. Measured Thermal-IR



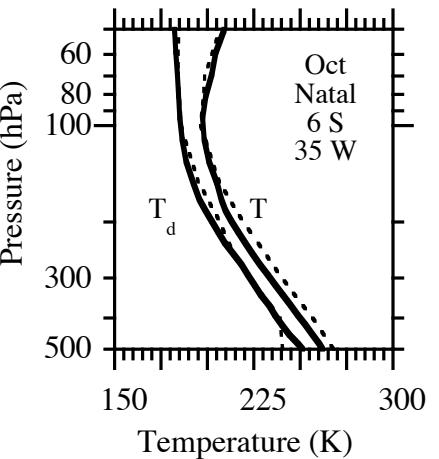
Data from Kiehl et al., 1998

Modeled vs. Measured Paired in Space Monthly T/T_d

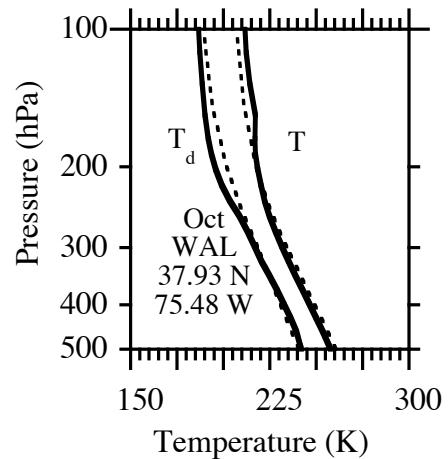
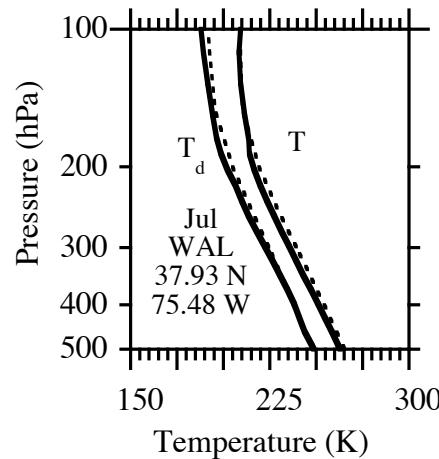
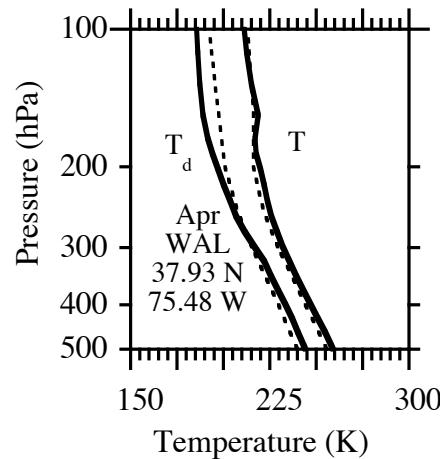
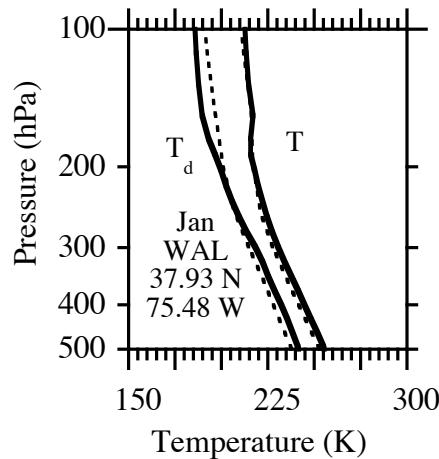
Global domain



Data from FSL (2008)



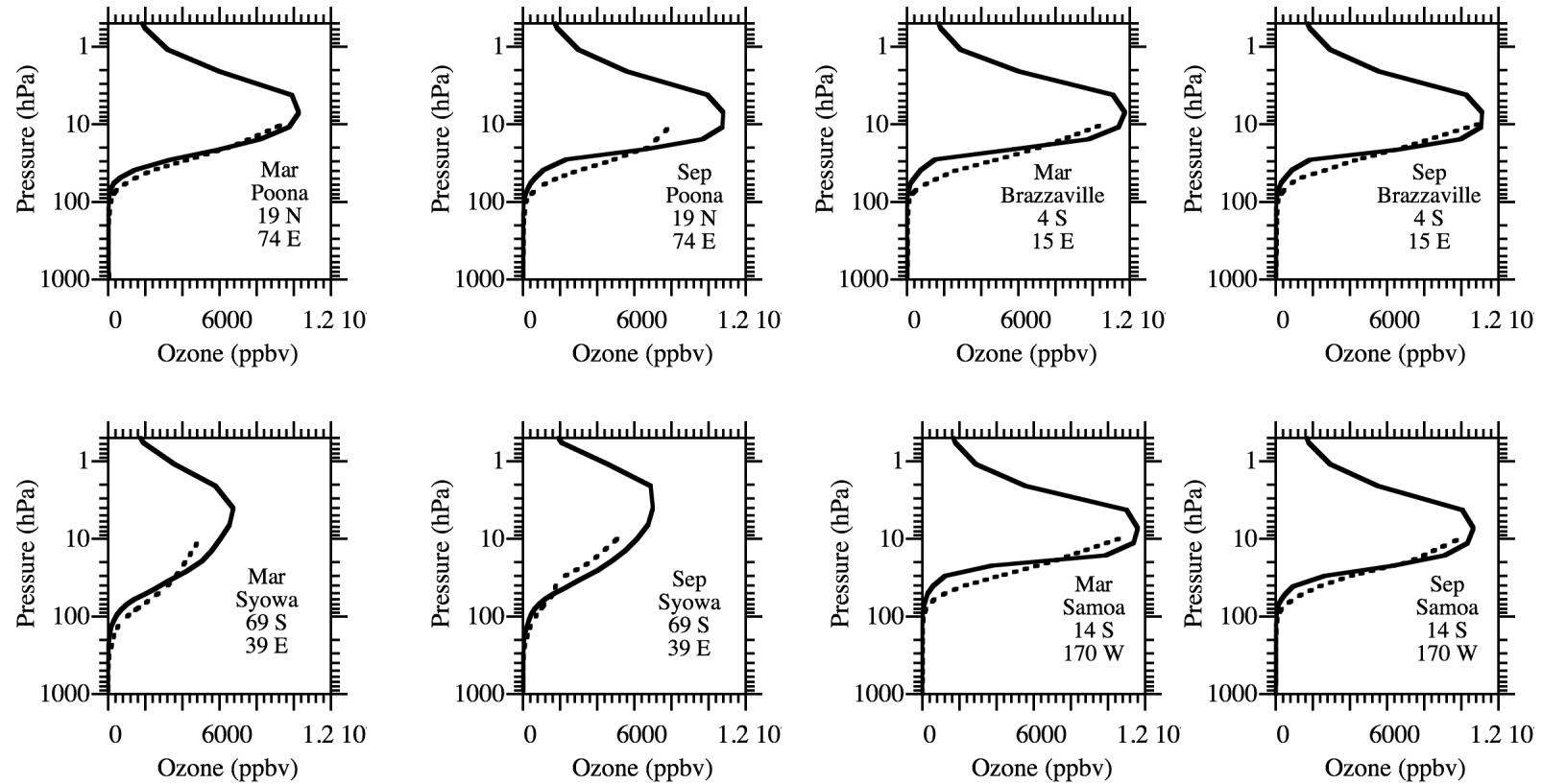
U.S. domain



Despite coarse resolution, model captures data features at exact location of data
- Little numerical diffusion of water vapor or energy to stratosphere

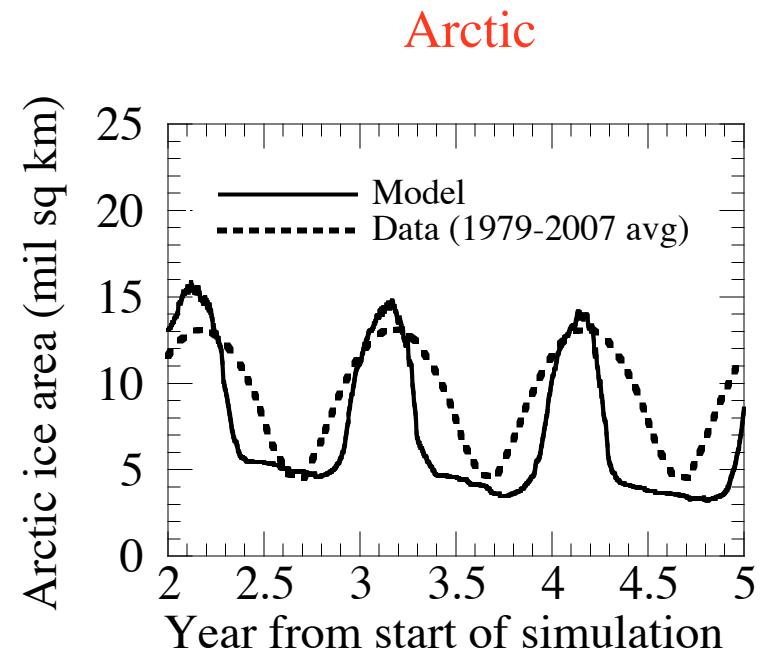
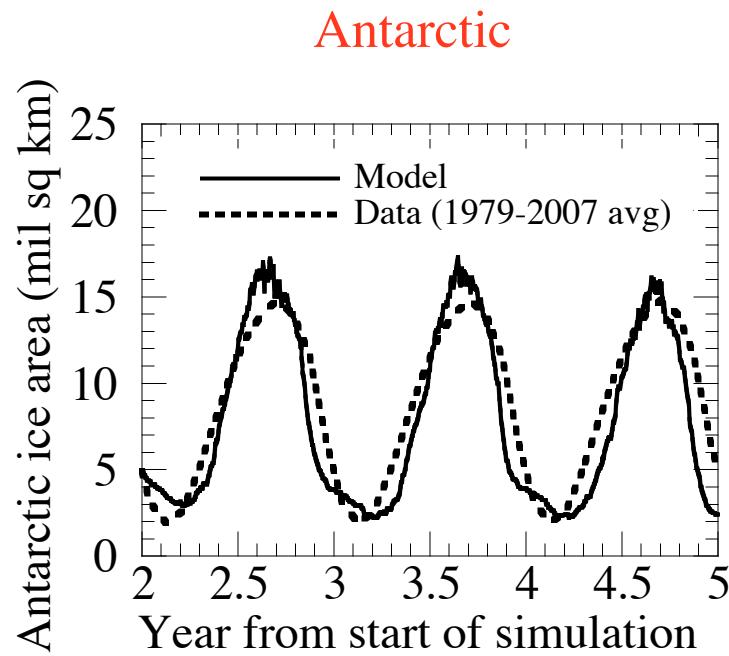
Modeled vs. Measured Paired in Space Monthly O₃

Data from Logan et al. (1999)



Model predicts the magnitude and altitude of the lower-stratospheric ozone layer

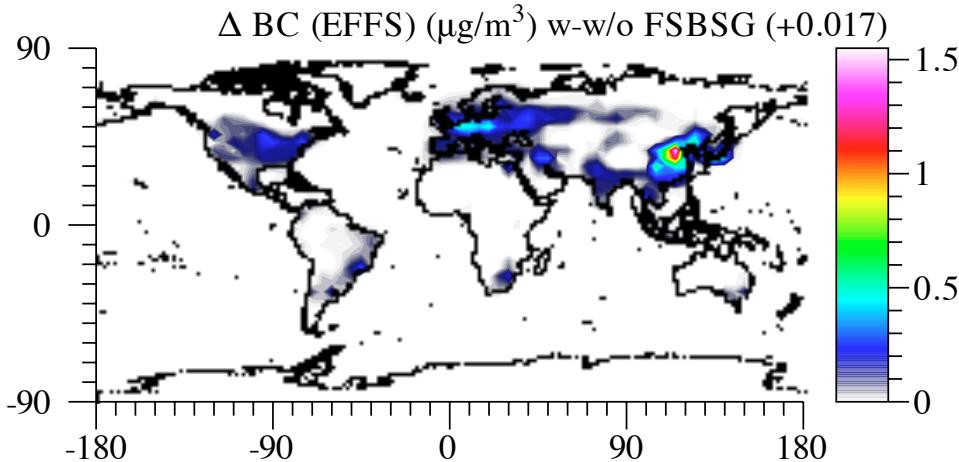
Modeled vs. Measured Sea Ice Area



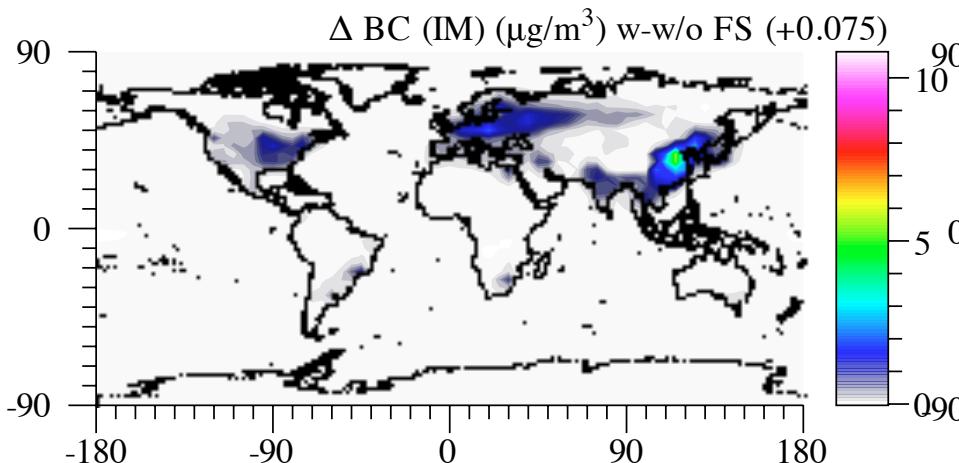
Model (at 4 x 5 degree resolution) predicts stable sea ice area after only two years of simulation

Data from NASA Team (2009)

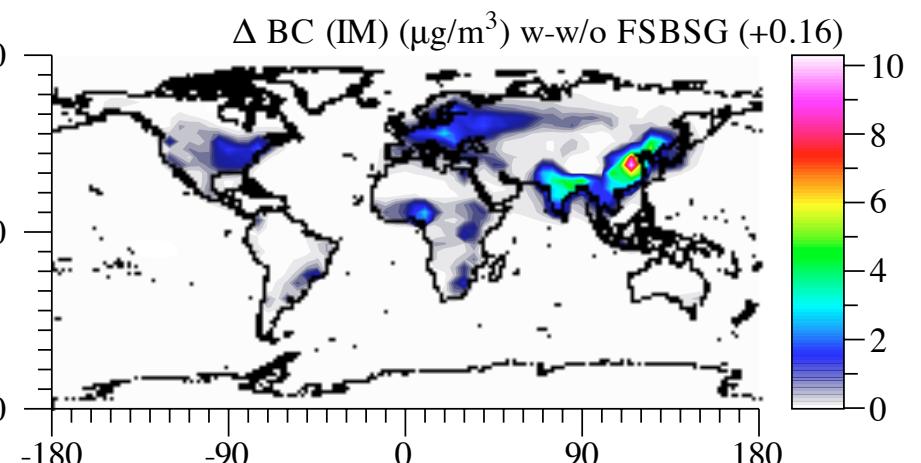
Externally- and Internally-Mixed BC Changes Due to FF +BF Soot + BF gases and to FF Soot Alone



FF soot

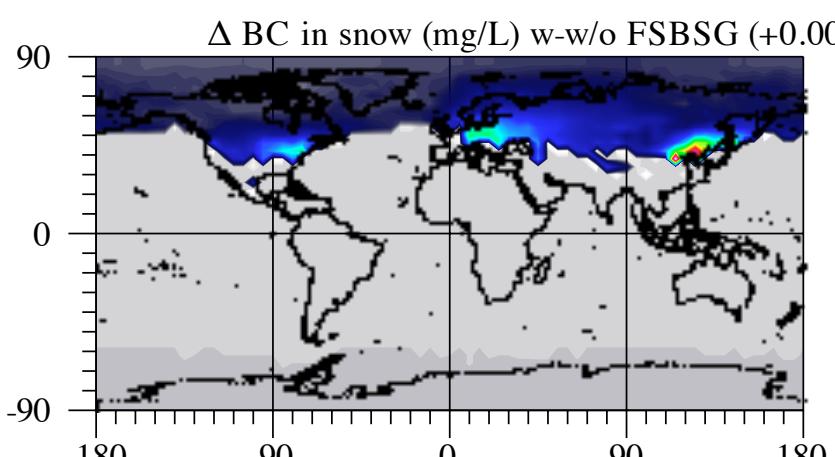


FF+BF soot + BF gases

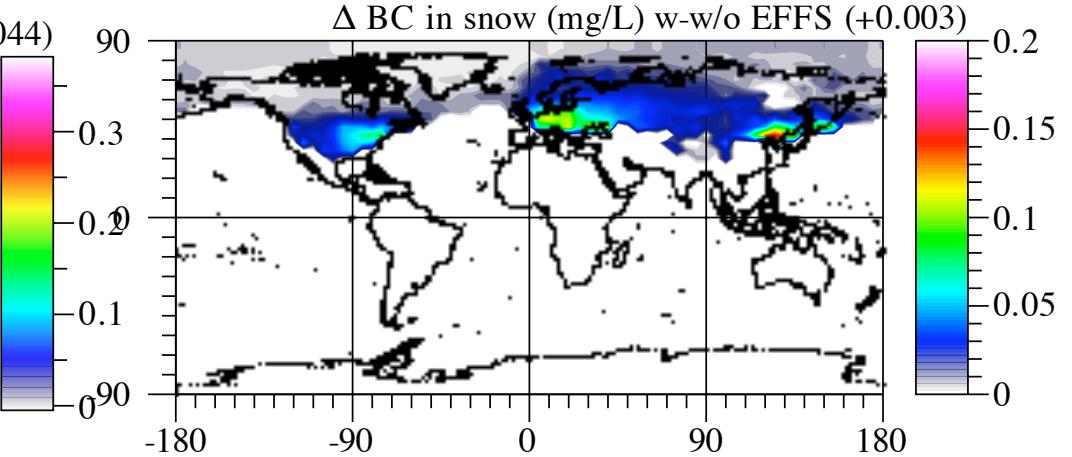


BC from FF soot about half that of BC from FF+BF soot +BF gases

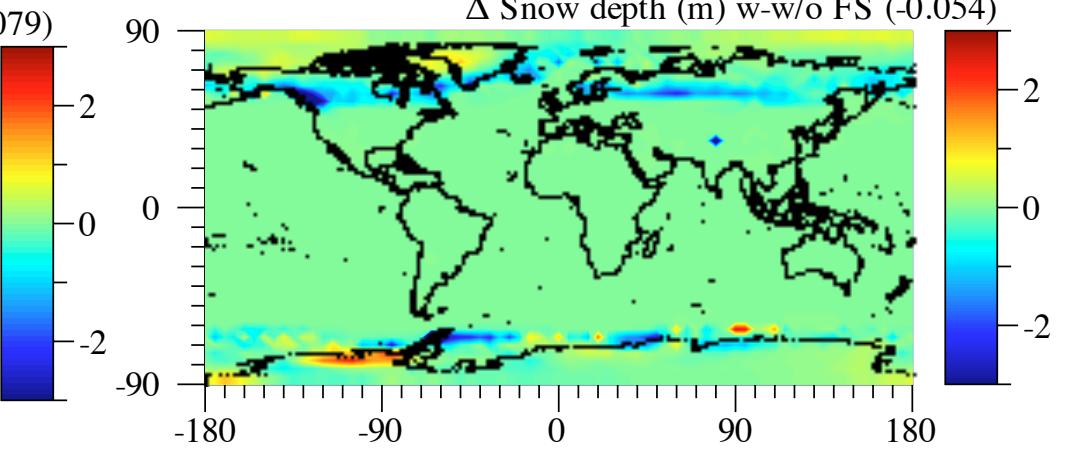
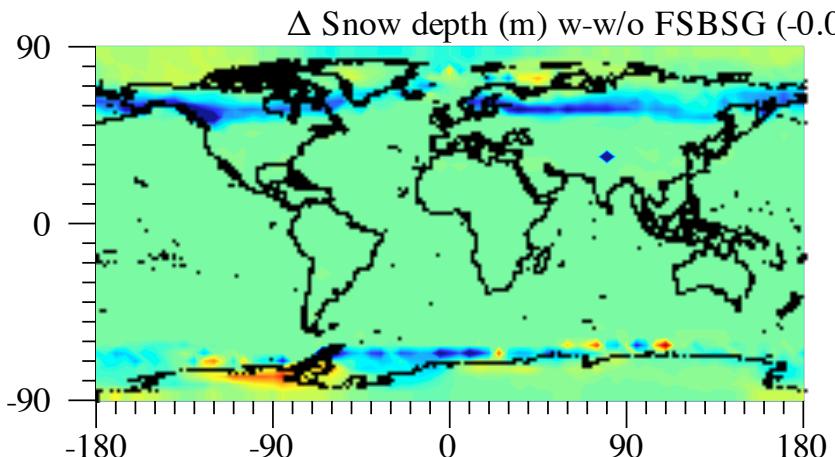
BC in Snow and Change in Snow Depth Due to FF+BF Soot + BF gases and FF Soot Alone



FF+BF soot + BF gases

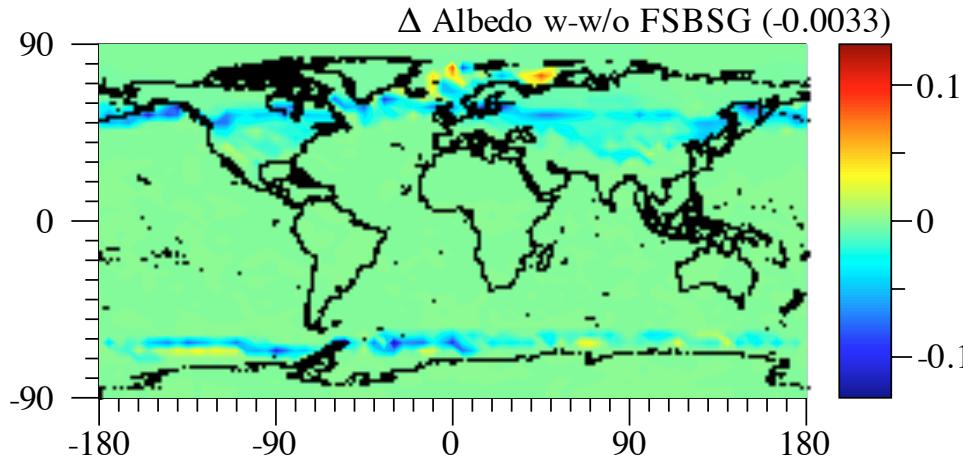


FF soot



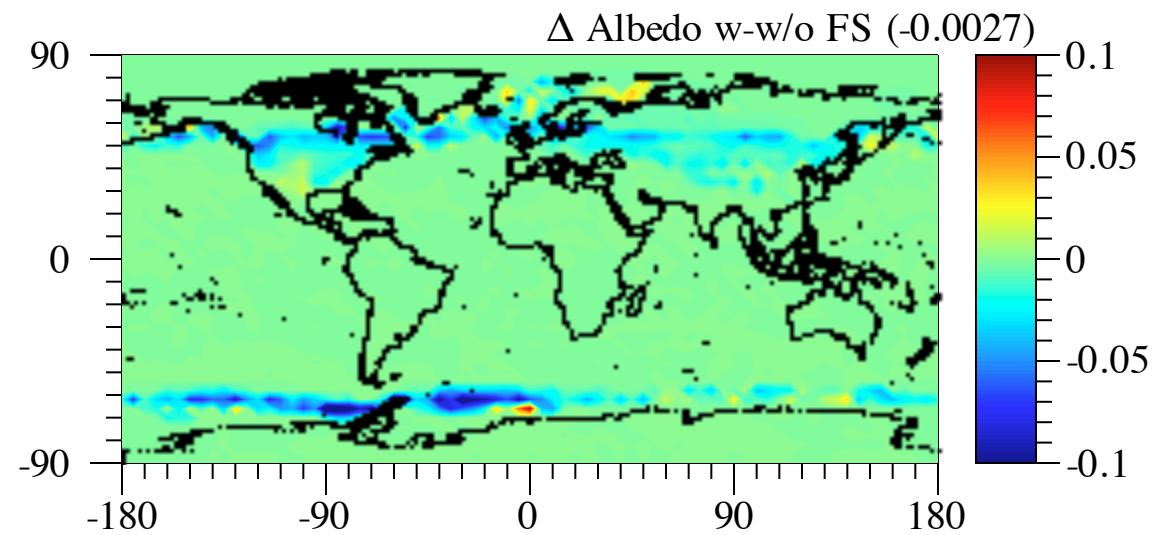
Both FF+BF soot +BF and FF soot inc. BC in snow & dec. snow depth

Surface Albedo Changes Due to FF+BF Soot + BF gases and to FF Soot Alone



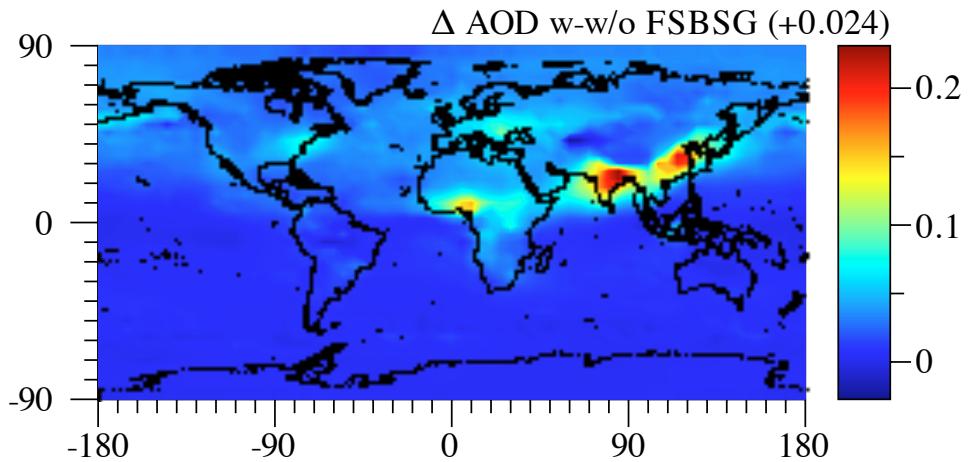
FF+BF soot + BF gases

FF soot

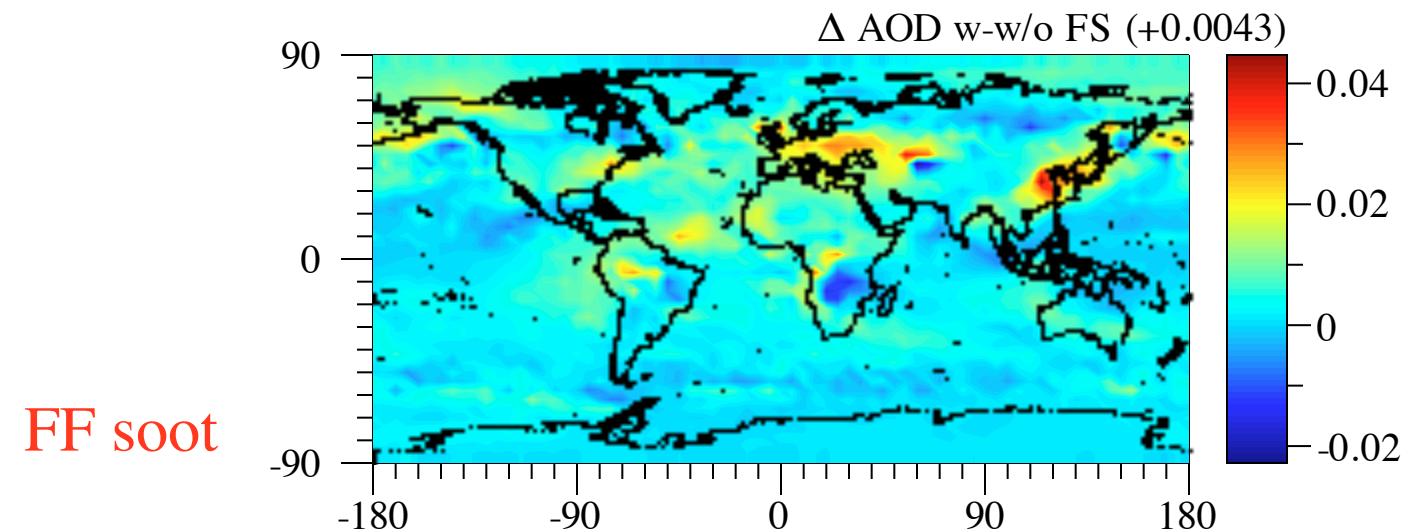


Most albedo loss due to FF+BF soot +BF gases is due to FF soot

AOD Changes Due to FF+BF Soot + BF gases and to FF Soot Alone



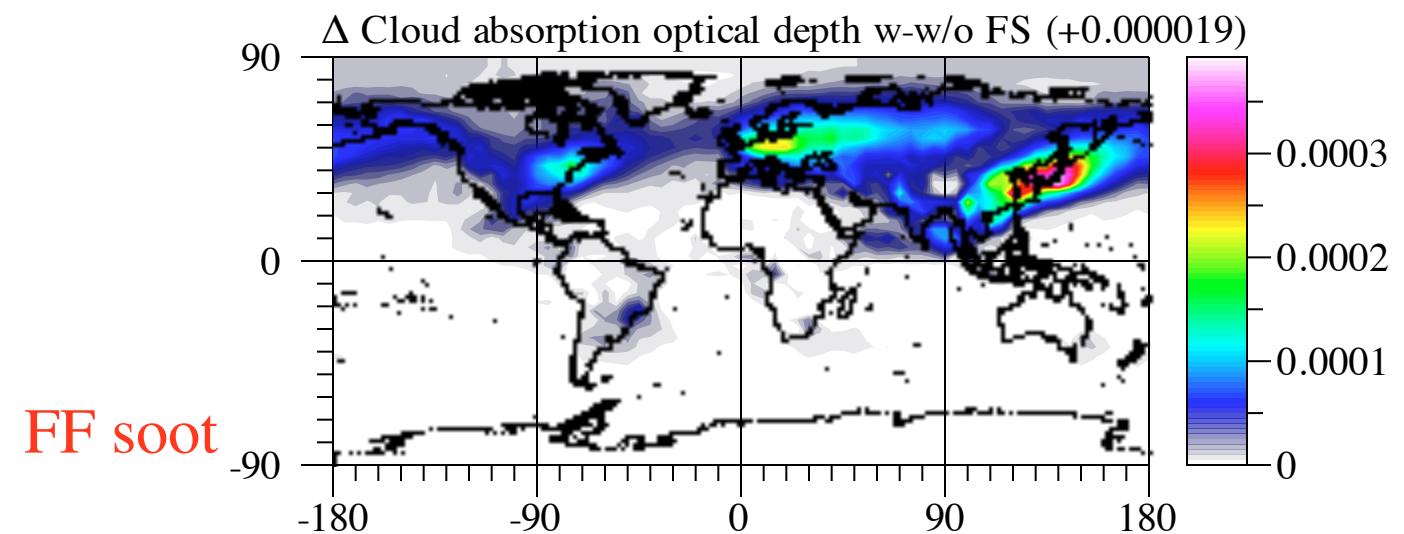
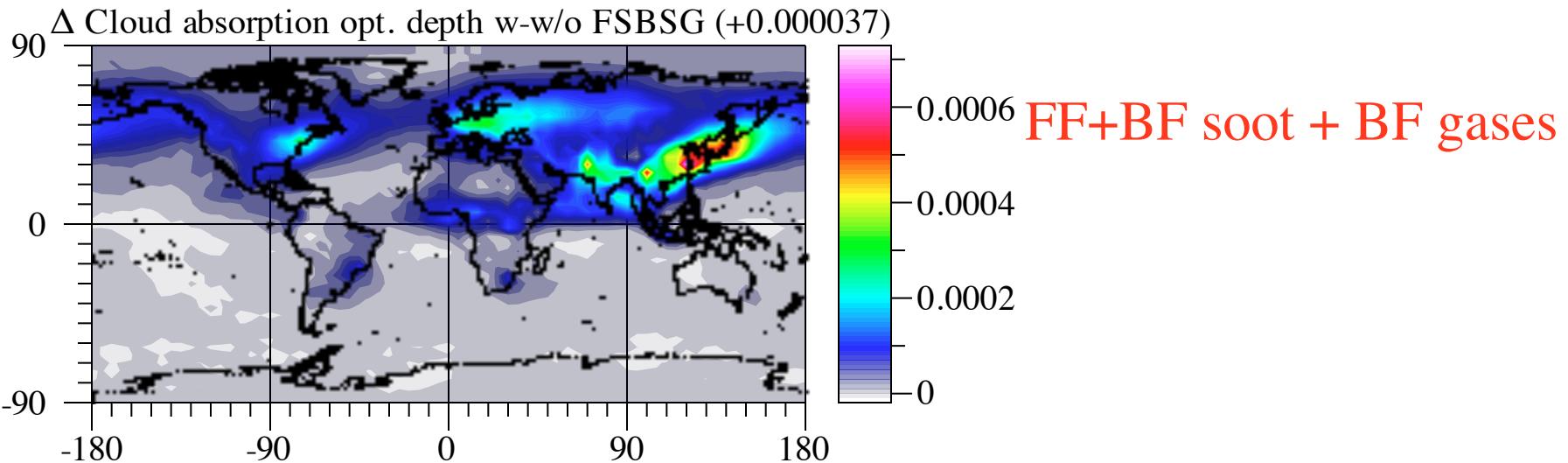
FF+BF soot + BF gases



FF soot

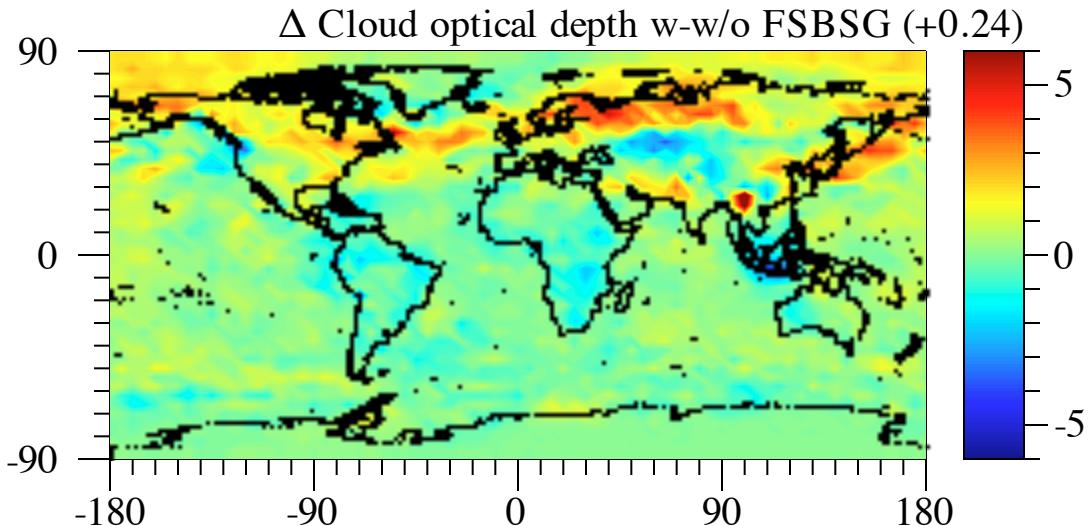
FF+BF soot +BF gases increased AOD more than did FF soot

Cloud Absorption Due to FF+BF Soot

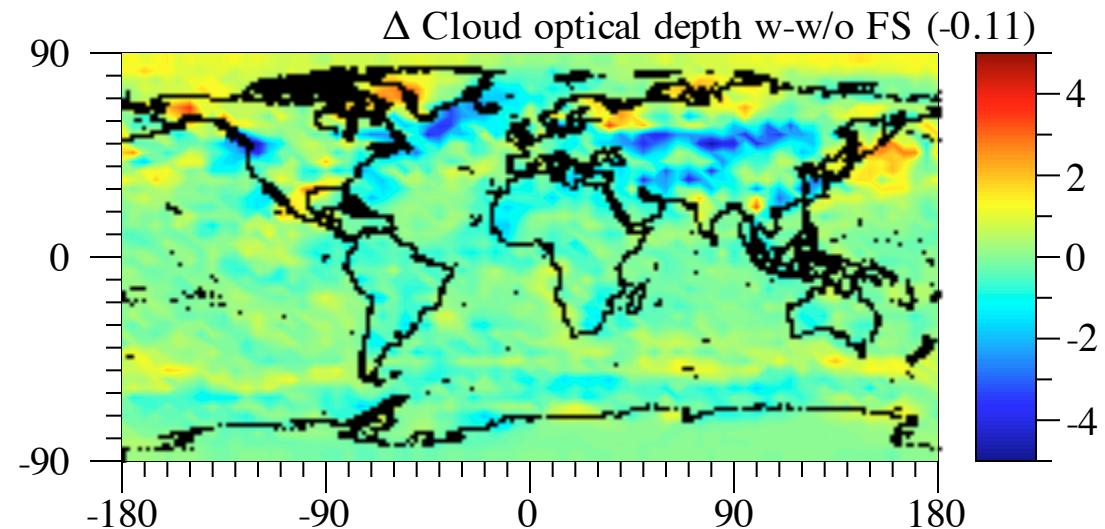


→ FF+BF soot + BF gases increased cloud absorption more than FF soot

Cloud OD Changes Due to FF+BF Soot + BF gases and to FF Soot Alone



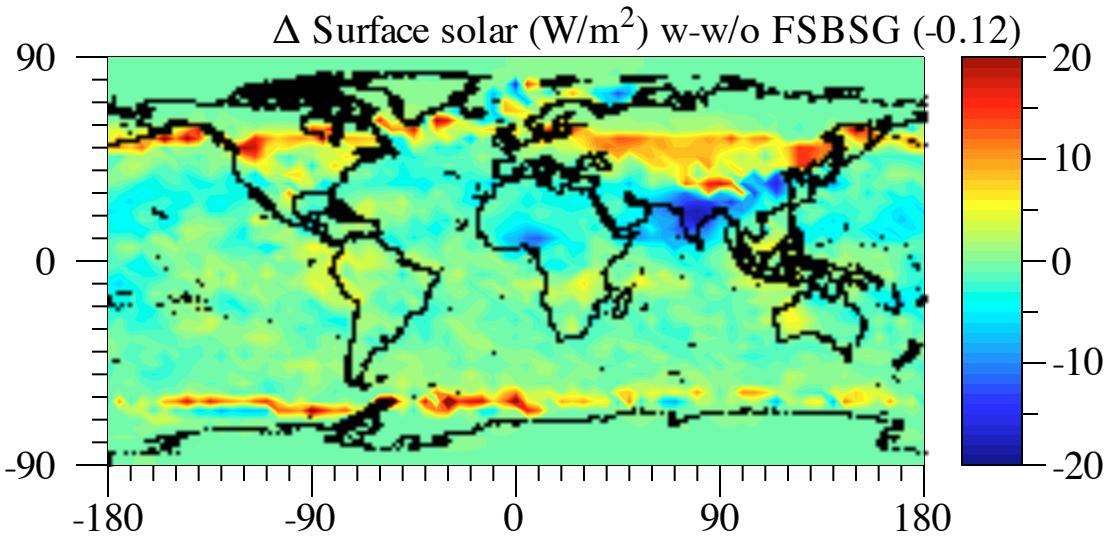
FF+BF soot + BF gases



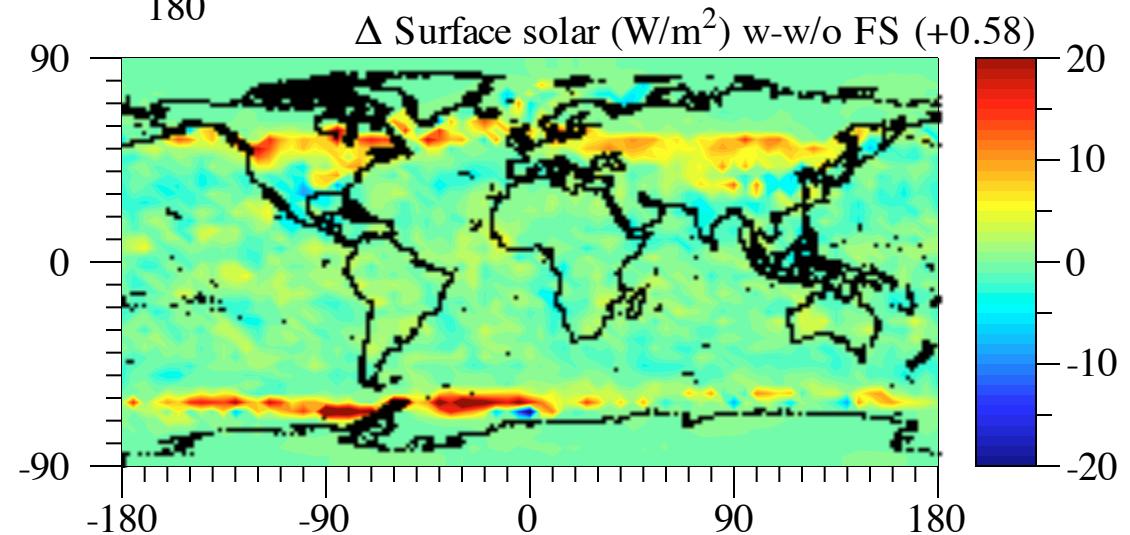
FF soot

FF+BF soot +BF gases increased COD; FF soot decreased COD

Surface Solar Changes Due to FF+BF Soot + BF gases and to FF Soot Alone

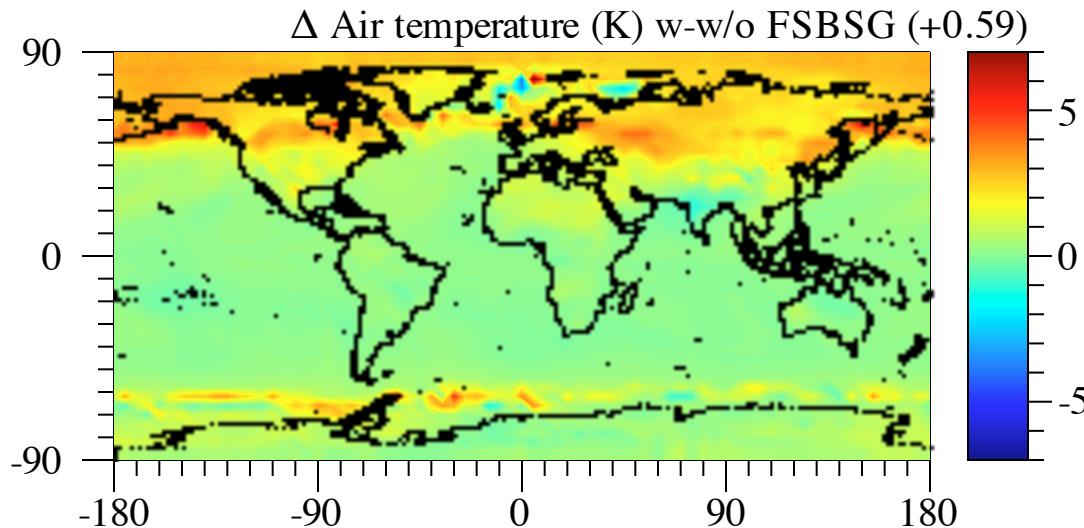


FF soot

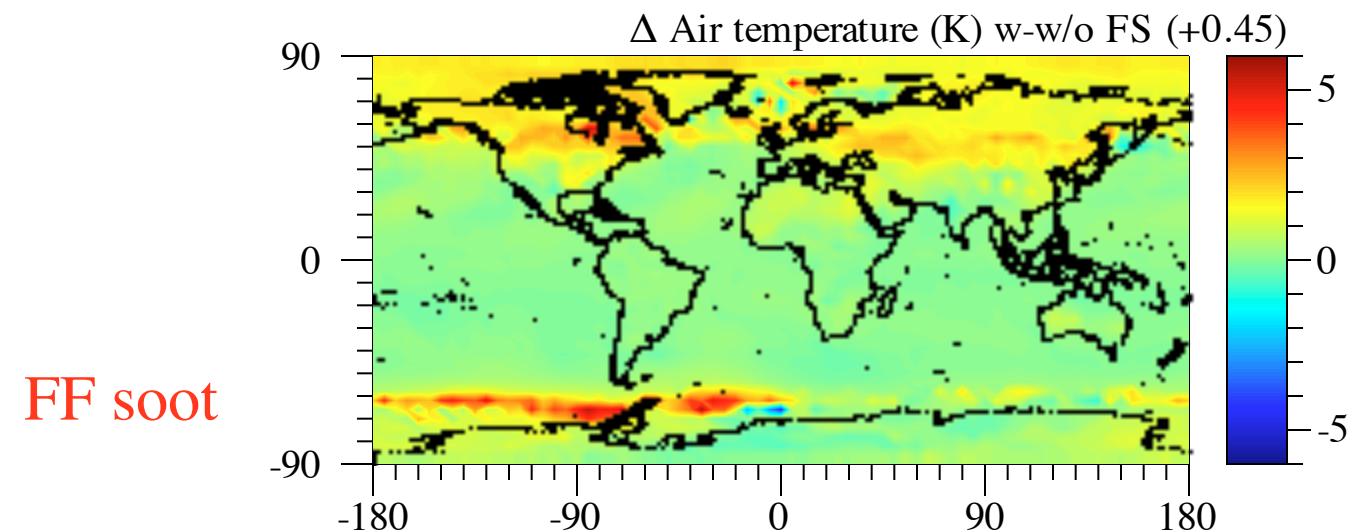


→FF+BF soot +BF gases decreased surface solar; FF soot increased it

Temperature Changes Due to FF+BF Soot + BF gases and to FF Soot Alone



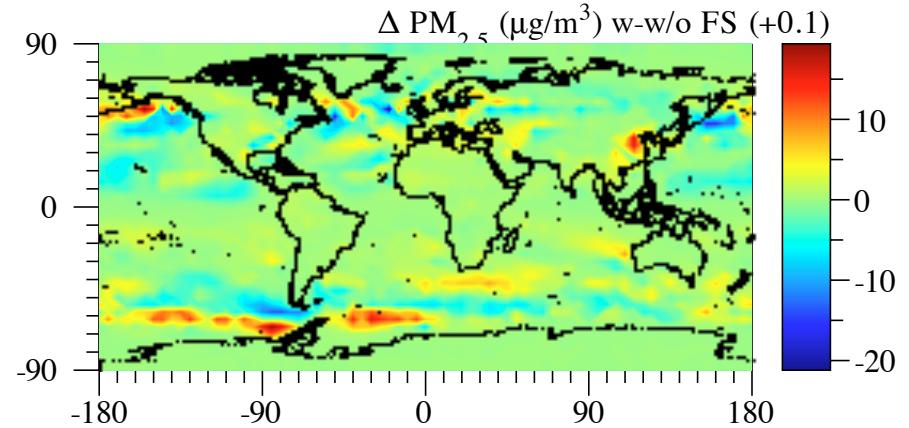
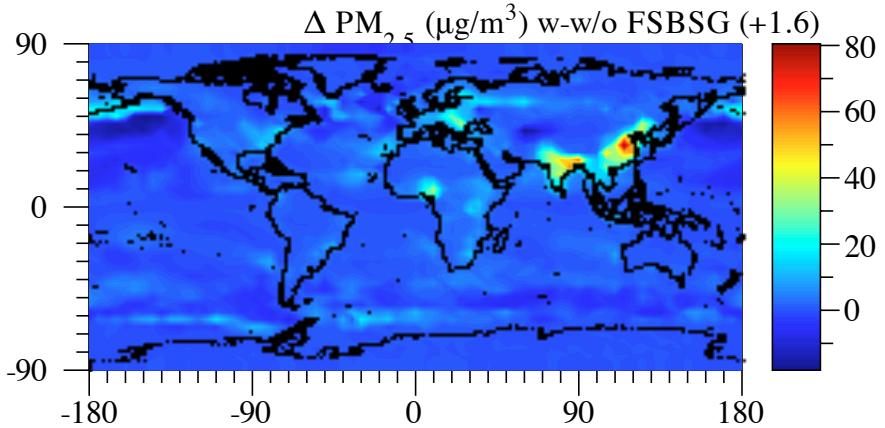
FF+BF soot + BF gases



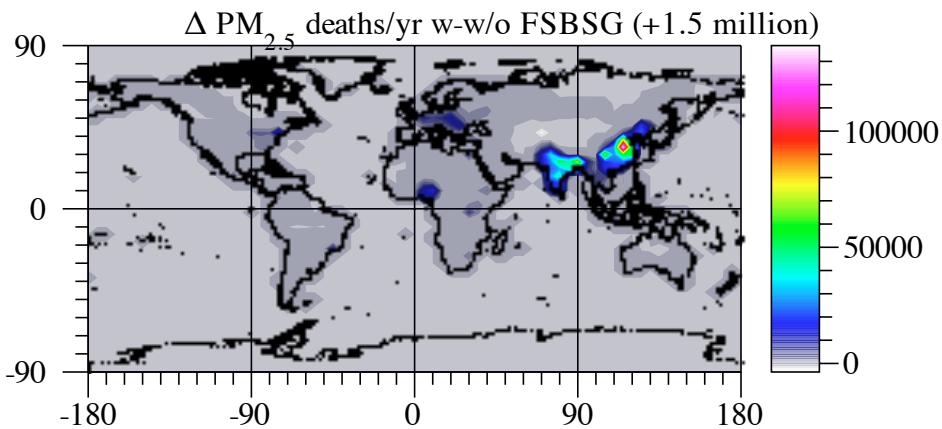
FF soot

Most temperature inc. due to FF+BF soot +BF gases is due to FF soot

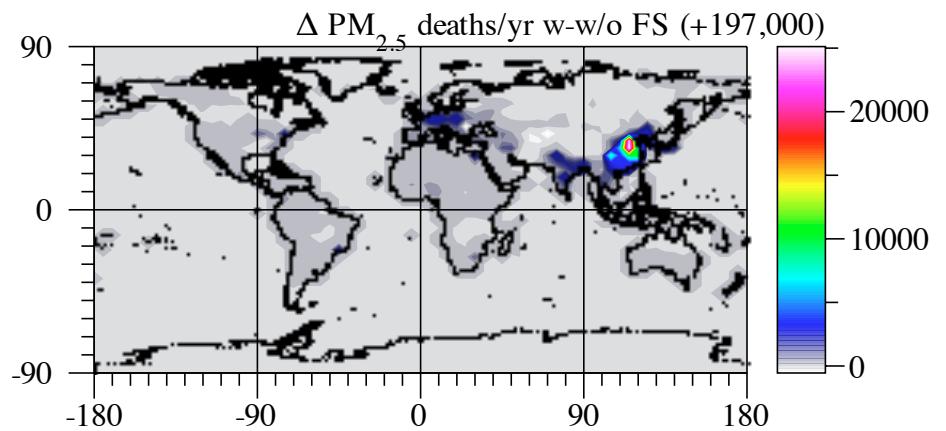
Changes in PM and Resulting Deaths due to FF+BF soot + BF gases and to FF soot



FF+BF soot + BF gases

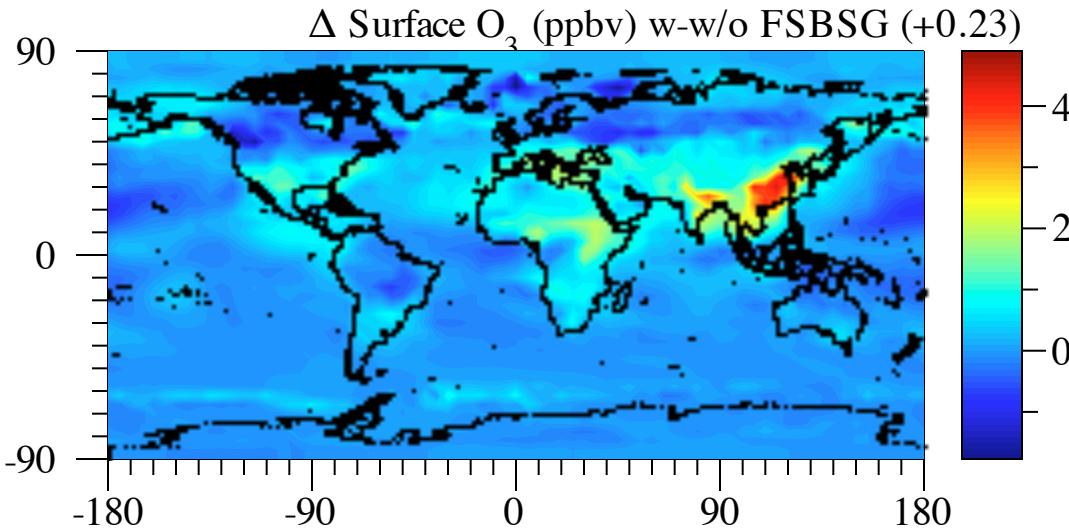


FF soot

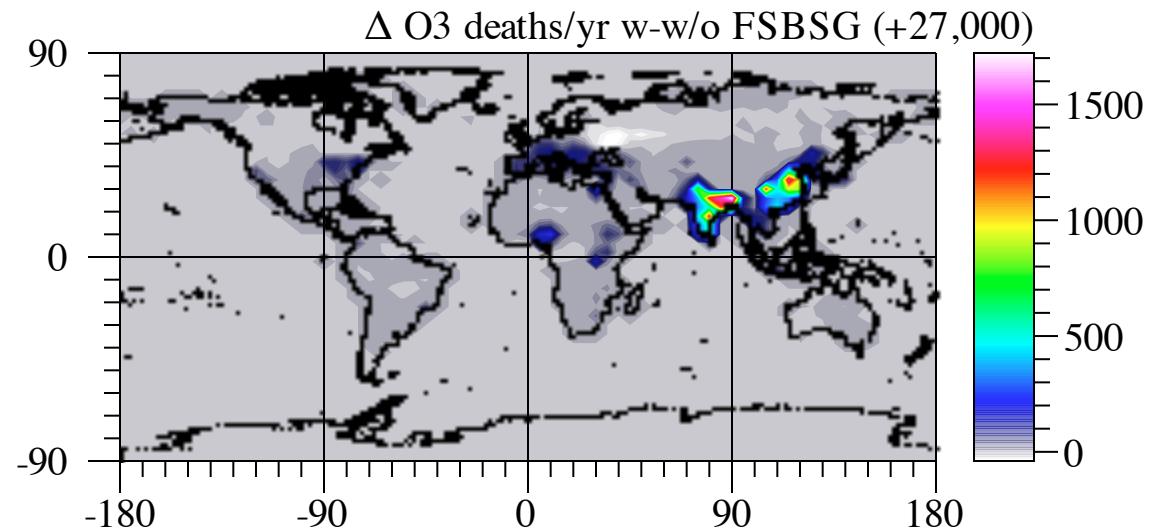


Deaths due to BF soot+gases ~7 times those due to FF soot

Changes in Ozone and Resulting Deaths due to FF+BF soot + BF gases

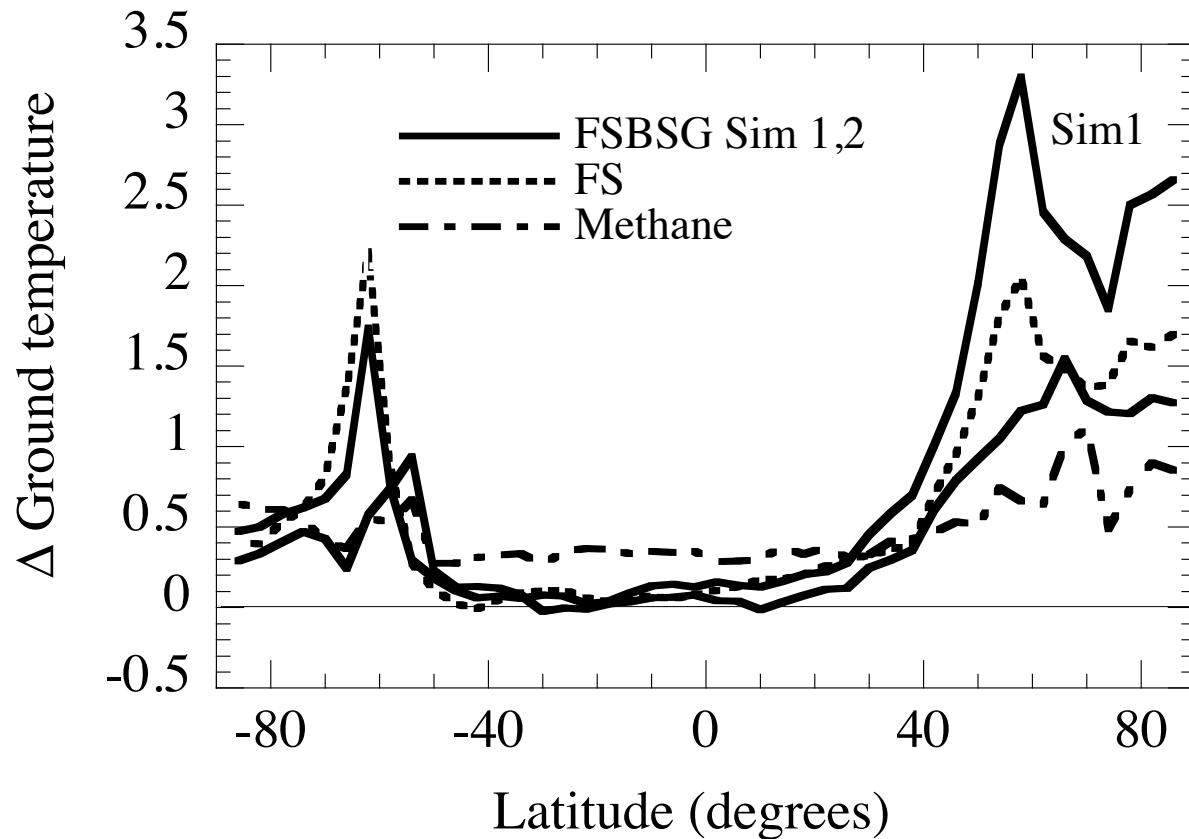


Ozone deaths



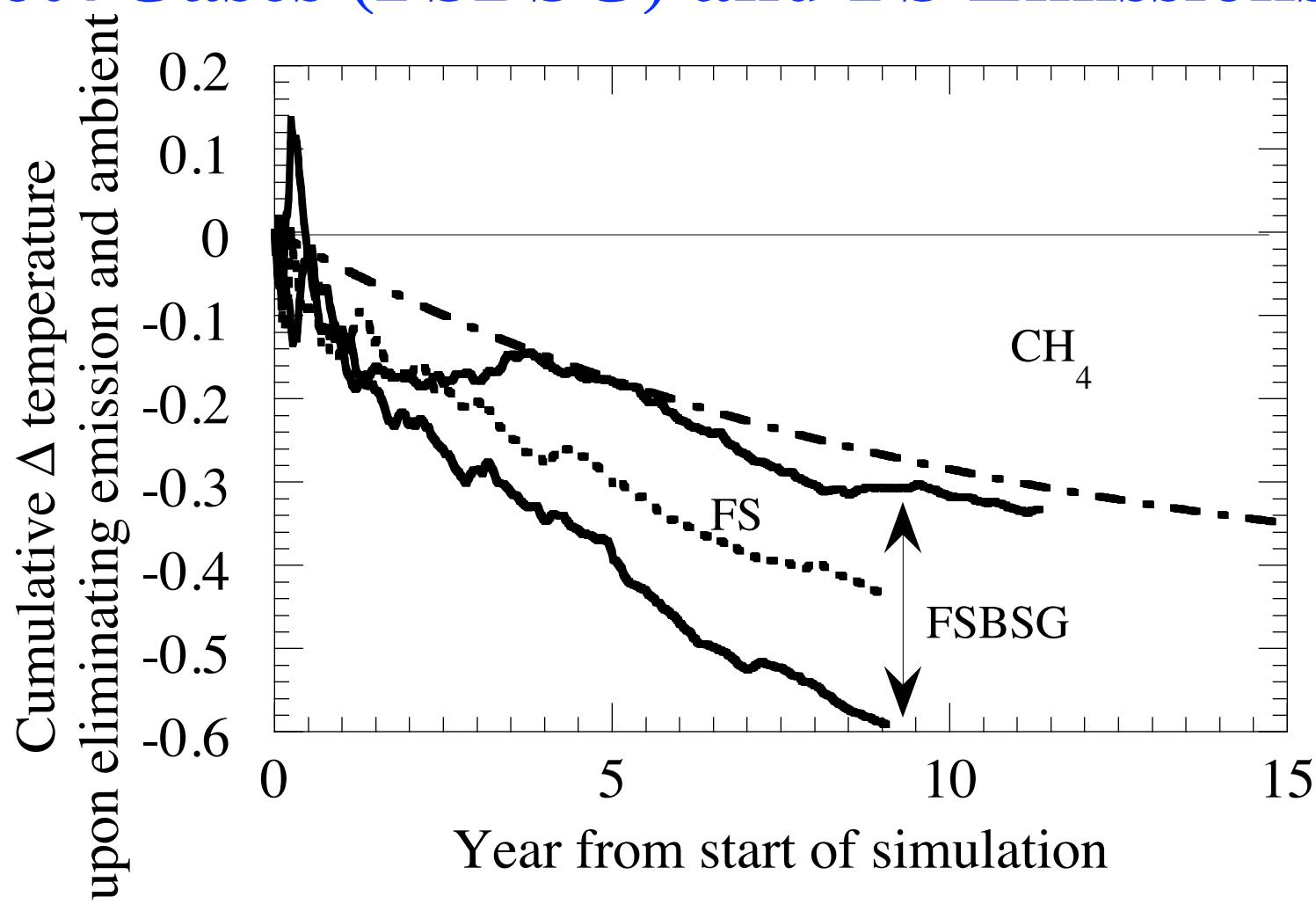
Biofuel burning increases ozone and ozone deaths

Arctic Warming Due to Anth. CH₄, Fossil Soot and Biofuel Soot+Gases (FSBSG), & FS

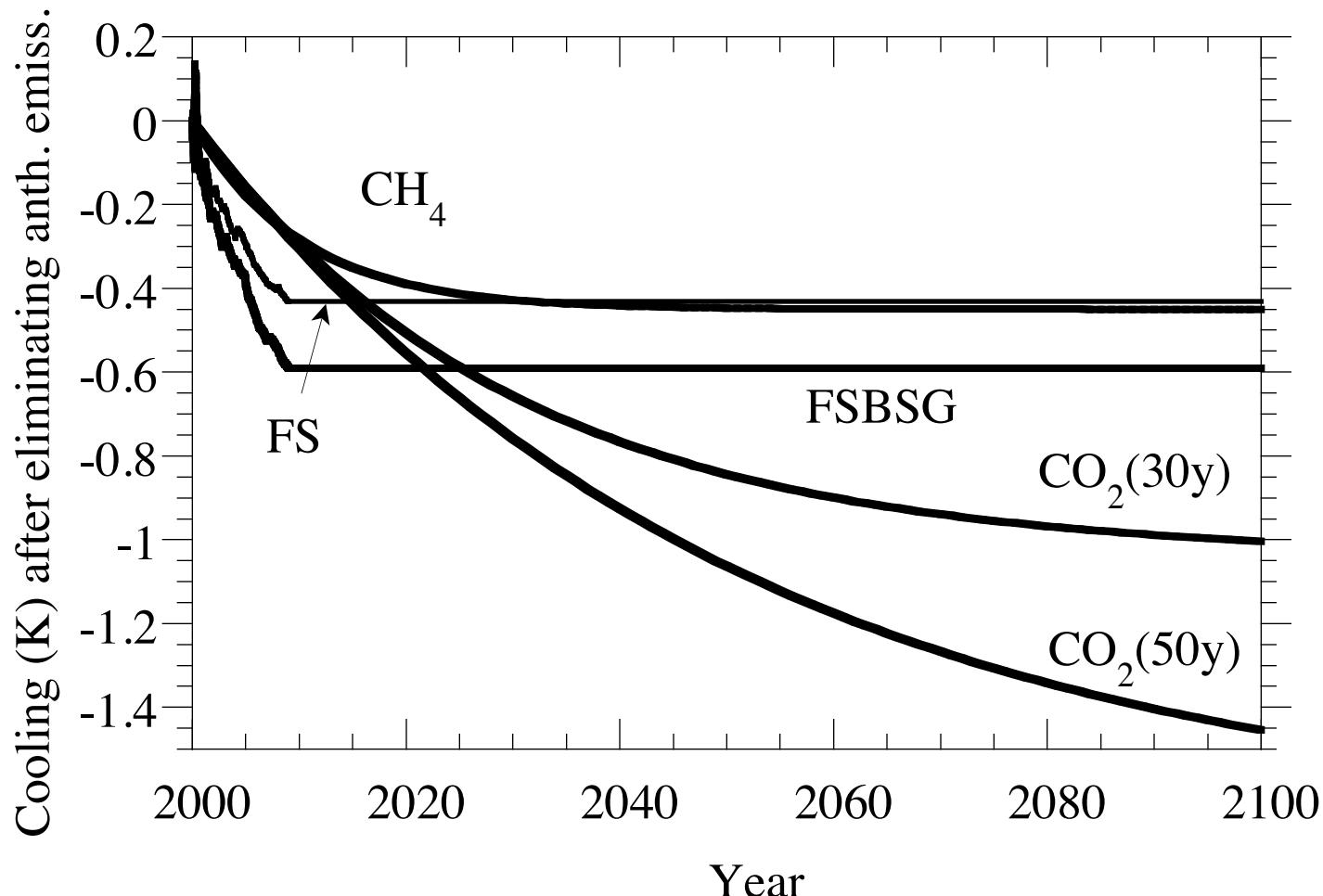


FF+BF soot + BF warm mid & high northern latitudes more than anthropogenic CH₄ or FF soot alone

Global Cooling Due to Eliminating Anthropogenic CH₄, Fossil Soot and Biofuel Soot+Gases (FSBSG) and FS Emissions only



Global Cooling Due to Eliminating Anthropogenic CO₂, CH₄, FSBSG, and FS Emissions only



FF Soot, BC Global Warming Potential

	20-yr STRE	100-yr STRE	100-yr STRM
BC+POC in FS	3250	1100-1600	650,000-960,000
BC in FS	6100	2700-3900	1.5-2.1 million
BC+POC in BSG	445	150-220	40,000-60,000
BC in BSG	2500	860-1250	400,000-600,000
Methane	86	29-43	21-31

STRE = Near-surface temperature change after 20 or 100 years per unit continuous emission of X relative to the same for CO₂ (similar to GWP e.g., 20-, 100-yr GWPS for CH₄ are 72, 25)

STRM = Near-surface temperature change after 20 or 100 years per unit mass in the atmosphere of X relative to the same for CO₂-C.

Summary

FSBSG soot is the second-leading cause of global warming behind CO₂ and ahead of CH₄. FS causes 3 x the warming of BSG, but BSG causes ~7x more deaths than FS.

FS alone may cause 0.3-0.45 K of global, 1-1.5 K Arctic warming
FSBSG may cause 0.35-0.6 K of global, 1.3-2.3 K Arctic warming
Methane may cause 0.3-0.45 K of global, 0.5 K Arctic warming

FF soot causes ~2/3 of the FF+BF soot warming since some cooling aerosols from BF burning offset some BF-BC warming.

The STRE (~GWP) of

BC in FS ~6100 over 20 yr and 2700-3900 over 100 years

BC in BSG ~2500 over 20 yr and 860-1250 over 100 years

Methane ~ 86 over 20 yr and 29-43 over 100 years

1 g ambient BC in FS warms 1.5-2.1 million x 1 g ambient CO₂-C.